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Agriculture and natural resource scientists' biodiversity information needs: Barriers and facilitators to use and access in the US Southeast

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Agriculture and Natural Resource Scientists' Biodiversity Information Needs: Barriers and Facilitators to Use and Access in the U.S. Southeast

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Abstract: In a study funded by the United States Geological Survey, a leading provider of biodiversity information, the University of Tennessee Center for Information and Communication Studies assessed the biodiversity information needs of southeastern US agriculture, natural resource management and other life scientists. Results reveal that 30% of agriculture and resource management scientists describe finding the biodiversity information they need as difficult. In addition, while agriculture and resource management scientists are better than other life scientists at searching for, finding and knowing where to find the biodiversity information they need to do their work, they experience significantly greater difficulty accessing that information. They also value different information source attributes and use information sources differently than do other life scientists. By understanding these and other aspects of agriculture and natural resource scientists' work with biodiversity information, information specialists, librarians, and information and professional organizations can help them maximize their research and practice efforts towards improved environmental outcomes.

Resumé: Dans une étude financée par le Service des études géologique des États-Unis, un des principaux fournisseurs de l'information sur la biodiversité, le Centre d'études en information et en communication de l'université du Tennessee a évalué les besoins en information sur la biodiversité du secteur agricole, des responsables de ressources naturelles et d'autres spécialistes des sciences de la vie du sud-est des Etats-Unis. Les résultats révèlent que 30% des scientifiques en agriculture et en gestion des ressources décrivent trouver difficilement l'information sur la biodiversité dont ils ont besoin. En outre, alors que les scientifiques en agriculture et gestion des ressources sont plus capables que d'autres spécialistes des sciences de la vie, de chercher, trouver et savoir où trouver l'information sur la biodiversité dont ils ont besoin pour faire leur travail, ils ont beaucoup plus de difficulté à obtenir ces informations. Ils ont également évalué différents attributs des sources d'information, et utilisent les sources d'information différemment des autres spécialistes des sciences de la vie. La compréhension de ceci et des autres manières de travailler des scientifiques en agriculture et ressources naturelles avec les informations sur la biodiversité, avec les spécialistes de l'information, les bibliothécaires et organisations professionnelles d'information peut les aider à optimiser leurs travaux de recherche et leurs efforts pratiques pour un meilleur environnement.

Resumen: En un estudio financiado por el Servicio Geológico de los Estados Unidos, un proveedor líder de información sobre biodiversidad, el Centro de Estudios de Información y Comunicación de la Universidad de Tennessee evaluó las necesidades de información sobre biodiversidad de científicos del sureste estadounidense que trabajan en los campos de la agricultura y del manejo de los recursos naturales, al igual que otros científicos de la vida. Los resultados indican que el 30% de los científicos que trabajan en los campos de la agricultura y el manejo de los recursos describen la búsqueda de la información que necesitan sobre biodiversidad como difícil. Además, mientras que los científicos que trabajan en los campos de la agricultura y el manejo de los recursos son mejores que otros científicos de la vida para buscar, encontrar y saber dónde encontrar la información que necesitan sobre biodiversidad para hacer su trabajo, ellos experimentan dificultades significativamente mayores para acceder a dicha información. También valoran diferentes atributos de las fuentes de información y utilizan fuentes de información de manera diferente a como lo hacen otros científicos de la vida. Al conocer estos y otros aspectos del trabajo de estos científicos con la información sobre biodiversidad, los especialistas en información, los bibliotecarios y las organizaciones de información y de profesionales pueden ayudarlos a maximizar sus esfuerzos de investigación y práctica para lograr mejores resultados ambientales.

Introduction

Agriculture and natural resource scientists, and other life scientists, use biodiversity information (information pertaining to plants, animals, habitats and/or ecological communities) as a key input for researching and managing food, fiber, and other biological systems. However, for information science professionals, identifying what kind of biodiversity information is most needed by these different types of scientists and how best to provide access to that information can be a challenge. While much work has focused on biodiversity related data gaps, information seeking, and research and analyses needs, less work has focused on biodiversity information needs related to using that data (Balmford et al. 2005). Scientific research is just one aspect of information needs (Hunt et al. 2007; McNie 2007; Tenopir, Allard, and Davis 2011); additional information needs include formats, parameters, and tools for finding, managing, and describing information. Furthermore, to our knowledge, no attempt has been made to discern the differences between the biodiversity information needs, practices and experiences of agriculture and natural resource scientists and those of other life scientists. While a strict distinction in information needs between these two related subject areas may not be entirely possible, such an assessment would go a long way towards streamlining the provision of research and data services as well as towards improving research, discovery and management.

The southeastern United States is a recognized global biodiversity hotspot for aquatic and amphibious resources.

This makes the biodiversity information needs of its scientists among the most critical to discern. The region's freshwater lakes, rivers, and streams contain the highest levels of diversity and endemism for freshwater mussels, crayfishes and fishes (Abell et al. 2000; Smith et al. 2002). Within specific taxonomic groups, on one or more measures of biodiversity, several southeastern states also rank high. For example, Alabama ranks first in freshwater fish diversity, followed by Tennessee, Georgia, Kentucky and Mississippi. The top four most diverse states in terms of amphibian diversity are North Carolina, Georgia, Virginia and Tennessee (Stein, Kutner, and Adams 2000).

This study, funded by the United States Geological Survey, a leading provider of biodiversity information in the United States, assesses the biodiversity information needs and seeking behavior of Southeast U.S. agriculture and natural resource scientists and other life scientists. The research questions include: 1) What biodiversity information is needed?, 2) What are the barriers and facilitators to finding biodiversity information?, 3) Where do agriculture and natural resources and other life scientists get the biodiversity information they need to do their work?, and 4) What characteristics of biodiversity information sources are valued?

Background

Biodiversity information needs are broader than simply filling particular research needs or data gaps (McNie 2007). For agriculture and natural resource scientists, and other life scientists, it is increasingly common for researchers to integrate diverse data sets and types. This requires information integration tools such as models that link environmental stressors to socio-economic impacts (Hunt et al. 2007; Vaughan et al. 2007), websites that unite information contained in multiple sites and databases (Kagan 2006) and maps that link scientific information specific to certain habitats within the geographies that host them (Theobald et al. 2005). Significant emphasis has also been placed on the utility of Geographic Information Systems (GIS) for data retrieval, organization and analysis (Laihonen et al. 2003; Neelakandan, Mohanan, and Sukumar 2006; Salem 2003). As Laihonen et. al. (2003) state, "biodiversity data or information lacking geographical dimensions have fairly little value from the point of view of end users."

Information integration also requires information from multiple scales. However, biodiversity information which matches the scale at which environmental decisions are made is frequently lacking. One possible result is that information is obscured, as forced scaling up or down is attempted (Cushing and Wilson 2005; Smythe, Bernabo, and Carter 1996; Tribbia and Moser 2008). Metadata is also necessary for both integrating information (Magness, Morton, and Hutton 2010) and identifying available information (Kelling 2006), but the lack of metadata use by scientists remains a concern (Tenopir et al. 2011).

Even when valuable biodiversity information exists, several barriers have been identified which may prevent scientists from finding, or making effective use of, needed information. Researchers must now navigate an often overwhelming "data deluge" (Hey and Trefethen 2003) brought about by recent advances in scientific data capture and storage capabilities (Bracke 2011). Simultaneously, according to Diekmann (2012), "data sets continue to be quickly lost to science and rarely remain accessible, much less usable, to anyone other than the original collector."

Online resources are essential. As one University of Minnesota faculty member states, "If it's not online, it's not visible" (Marcus et al. 2007). Conference literature and gray literature can be particularly difficult to locate. This is especially important for staying current, a major challenge but also viewed by researchers as one of the most important things to do (Marcus et al. 2007). For these reasons, several authors note the need for improved information search skills, training and tools (Cullen, Cottingham, and Doolan 2001; Janse 2006; Szaro et al. 1998; Kagan 2006).

The biodiversity information sources consulted by agriculture and natural resource scientists, and other life scientists, are numerous and varied. A survey of forty three active natural resource managers in mostly U.S. federal resource management agencies conducted by the non-profit organization NatureServe found respondents "regularly visit a diverse array of websites to look up biodiversity information" (Young 2011). Forty four separate websites were mentioned. The most popular in decreasing order were NatureServe Explorer, USDA Plants, various specimen sites (Fishbase, Arctos, GBIF, herbaria, etc.), state heritage program websites, and the United States Fish and Wildlife Services' Environmental Conservation Online System. In a literature review of crop sciences articles, Williams (2012) found 44% of 124 crop sciences articles used a data source other than traditional literature. These included data from other published articles, supplementary files associated with other publications, data from growers, data from weather stations, unpublished data, and GIS spatial data layers. In the United Kingdom, on the other hand, the Research Information Network and British Library's survey of life science researchers concluded they use a limited range of services to discover and gain access to the information they need, mostly web based bibliographic search and retrieval tools, online publications and websites they trust. As a result, researchers relied upon informal advice from colleagues (Research Information Network and the British Library 2009).

Several studies have tried to identify what scientists define as useful attributes of biodiversity information sources. Findings include currency (Laihonen, Kalliola, and Salo 2004; Diekmann 2012; Young 2011), usability (Laihonen, Kalliola, and Salo 2004; Research Information Network and the British Library 2009; Young 2011), and interoperability of systems and software (Research Information Network and the British Library 2009). In addition, the Research Information Network and British

Table 1 – Primary work sectors and subject disciplines

Primary Subject Discipline (n = 169)	%	% of Primary Subject Discipline in Each Work Sector: Academic	Government	Not for Profit	For Profit
Life Sciences	67.5	57.9% (66)	21.9% (25)	17.5% (20)	2.6% (3)
Agriculture & Natural Resources	32.5	67.3% (37)	14.5% (8)	16.4% (9)	1.8% (1)
Total	100%	60.9%	19.5%	17.2%	2.4% (4)

Library concluded that U.K. life scientists were less interested in completeness and specificity than accessibility and trustworthiness (2009).

Methods

In the fall of 2010 and early winter of 2011, we invited southeastern U.S. life, agriculture and natural resource and physical scientists to take an internet survey. We developed thirty four survey questions to address the four research questions plus demographics. For this project, the "southeast" was defined as Tennessee, Georgia, North Carolina, South Carolina, Kentucky, Florida, Alabama, and Mississippi. Invitations were e-mailed to attendees of regional topically related conferences, United States Geological Survey (USGS) identified contacts, regional herbaria contacts, university based researchers, and non-profit organization and fish and wildlife agency contacts (n = 8597). Contact information was found by browsing appropriate university, non-profit and agency websites.

The total response (n = 457) represents those southeastern environmental scientists, resource managers and decision-makers involved with and interested in biodiversity information. For this paper, only data associated with respondents who identified their primary subject discipline as "Agriculture and natural resources (forestry, wildlife, plant and soil sciences, etc.)" and "Life Sciences (biology, botany, ecology, zoology, marine biology, etc.)" is analyzed (n = 169). These respondents represent more than three fourths (76%) of all respondents who provided a primary subject discipline.

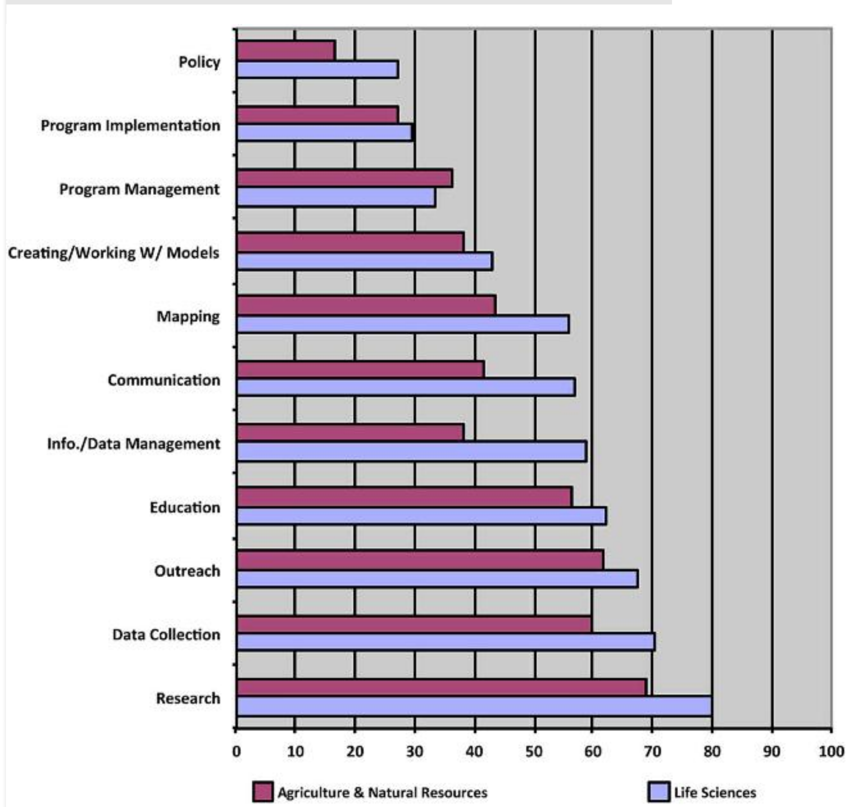
The survey was administered via mrInterview hosted by the University of Tennessee's Statistical Consulting Center's DimensionNet server. The results were analyzed with SPSS 18.0.

Results

More than two-thirds of the sample describe themselves as life scientists, while just over one third categorize themselves as primarily agriculture and natural resource scientists (Table 1). Reflecting the proportions of invitations sent, these respondents come mostly from the academic work sector (60.9% n = 103), with one fifth (19.5%, n = 33), coming from the government sector (Table 1). The majority of the remaining respondents, 17.2% (n = 29) work in the non-profit sector. Life science respondents are more likely than agricultural respondents to work in the government sector (80% federal, 20% state), while agricultural respondents are more likely to be academics.

Most respondents' primary role with respect to their biodiversity work is research (55.6% agriculture and natural resource, 52.6% life sciences), followed by education (16.7% agriculture, 15.8% other life sciences), with biodiversity related program managers and "other" at approximately 11% each. All respondents include a variety of the eleven biodiversity related activities measured in their work (Figure 1). However, life science respondents are more likely than agriculture and natural resource respondents (by 10–20%) to include research, data collec-

Figure 1 – Engagement in biodiversity related work activities



tion, information and/or data management, communication, mapping, and policy. For information and/or data management the difference is significant ($p < .05$). Program management is the only biodiversity related activity in which more agriculture and natural resource respondents than other life science respondents are engaged (Figure 1). Most respondents describe their data as biotic surveys and experiments.

Table 2 – Degree of difficulty in finding needed biodiversity information

	Agriculture & Natural Resources (n = 55)	Life Science (n = 112)	Total (n = 167)
Easy/Extremely Easy	23.6%	26.8%	25.7%
Neither Difficult or Easy	47.3%	50.9%	49.7%
Difficult/Extremely Diff.	29.1%	22.3%	24.6%

What biodiversity information is needed? – On a scale of 1 = None, 3 = Half and 5 = All, the mean amount of biodiversity information respondents need to do their work is 3.64. This amount is significantly less for agriculture and natural resource respondents (mean = 3.39) than for other life science respondents (mean = 3.76, $p < .05$). Proportionately, for more than 80% of all respondents, information specifically related to biodiversity is half or more than half the information they need to do their work. This is also the case for nearly 90% of life scientists (86.7%) and 72% of agriculture and natural resource respondents.

Unfortunately, one-quarter of all respondents say it is difficult or extremely difficult to find the biodiversity information they need (Table 2). The same is essentially true for life scientists. Agriculture and natural resource scientists have even more difficulty. Most respondents, though, say finding the biodiversity information they need is neither difficult nor easy.

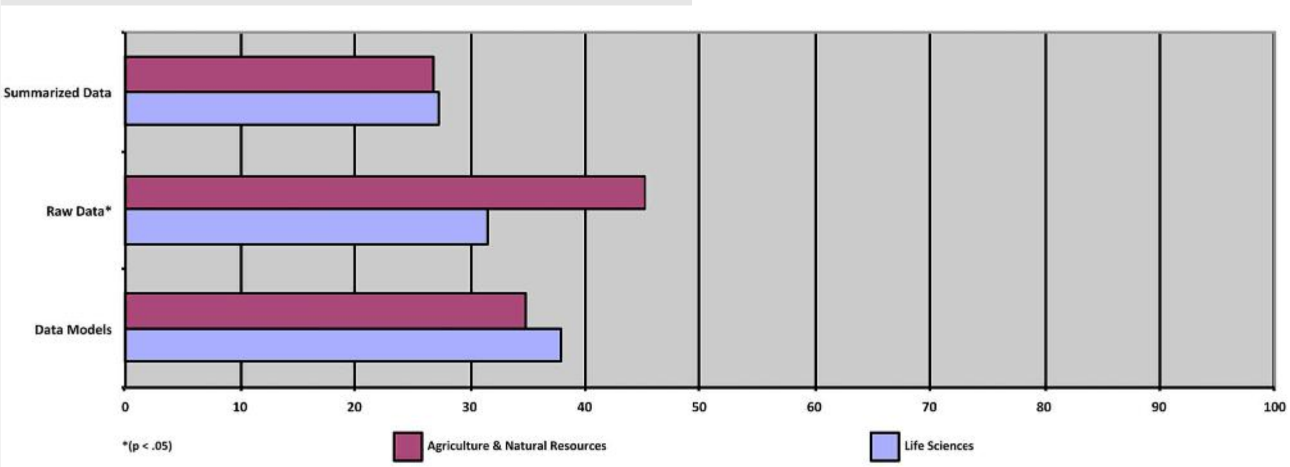
Respondents were also asked what biodiversity information they would like to have but have been unable to find. Most responses reference occurrence, life history, and distribution information, while access to historical literature was also frequently cited. With all responses, several interesting caveats were noted including the importance of easy online access, and that only data that was accurate, current or trustworthy was useful. At least one life science respondent noted that access to a better "roadmap" to find information would be useful.

In terms of different types of biodiversity information, respondents need raw data more (mean = 3.22, same scale as above) than summarized data (mean = 2.99). Life science respondents need significantly more raw data (mean = 3.38) than do agriculture and natural resource respondents (mean = 2.89, $p < .05$), with 80% reporting raw data as at least half the information they need to do their work. Only half the agriculture and natural resource respondents need this much raw data. Agriculture and natural resource respondents are slightly more likely than life science respondents to report summarized data as half or more than half the biodiversity information they need to do their work (69% agriculture compared to 61% life science).

Data models were measured in terms of their importance to respondents' biodiversity work (1 = Not at all important, 2 = somewhat important, 3 = neither important nor unimportant, 4 = important, 5 = essential). Overall, data models are neither important nor unimportant to respondents (mean = 3.14). The same is essentially true for both disciplines (mean agriculture and natural resources = 3.3, mean life sciences = 3.06).

Approximately one-third of all respondents report each data type as difficult or extremely difficult to find. More agriculture respondents report difficulty finding raw data than summarized data or data models, while more life science respondents report difficulty finding data models, followed by raw data and summarized data (Figure 2). No significant differences were found between disciplines or between data types.

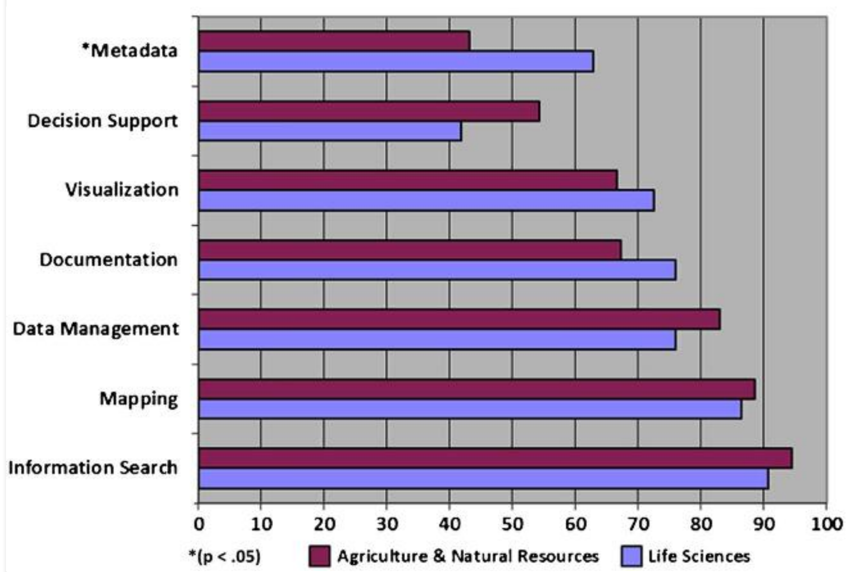
Figure 2 – Percent of respondents who say finding three different biodiversity data types is difficult or extremely difficult



In open ended comments, life science respondents described not being able to find reports and literature they know exists. A few mentioned a need for a centralized database of biodiversity related data. In addition, at least one life science respondent noted that without good data description raw data is useless. Another commented that the volume of data is overwhelming. Few agriculture and natural resource respondents provided differing comments on raw data. In terms of summarized data, they require information related to making management decisions.

To gauge what biodiversity information tools agriculture and natural resource and other life scientists need, participants were asked how important seven different biodiversity information tools were for doing their biodiversity work (Figure 3). All the tools measured show importance to respondents with means ranging from 3.82 for decision support tools to 4.35 for information search tools with no significant mean differences between disciplines. However, when looking only at the proportion of respondents who rate these tools as important or very important, a significant difference between disciplines in the importance of metadata tools is revealed (Figure 3). Significantly more life science respondents than agriculture and natural resource respondents rate metadata tools as important or very important to their biodiversity related work. Interestingly, slightly more agriculture and natural resource than life science respondents rate data management, mapping and information search tools, all of which at least in part rely upon good metadata, as important or very important to their biodiversity related work. In addition, it is clear that more agriculture and natural resource respondents find decision support tools important than life science respondents.

Figure 3 – Percent of biodiversity information tools rated important or very important



Biodiversity information tools have been slightly easier for respondents of both disciplines to find than biodiversity information itself. On a five point scale from 1 = Extremely Easy to 5 = Extremely Difficult, the overall mean ease of finding biodiversity tools is 3.11. Means for both disciplines are similar (mean agriculture = 3.08, mean life science = 3.12). Proportionately, only 23.6% of agriculture and natural resource and 16.7% of life science respondents report difficulty or extreme difficulty finding the biodiversity information tools they need to do their work.

Finally, respondents were asked which geographic scale they used most frequently in their biodiversity information work. Smaller, more localized scales are used most often by all respondents (Figure 4). Agriculture and natural resource respondents used state and local

Figure 4 – Geographic scale most frequently used

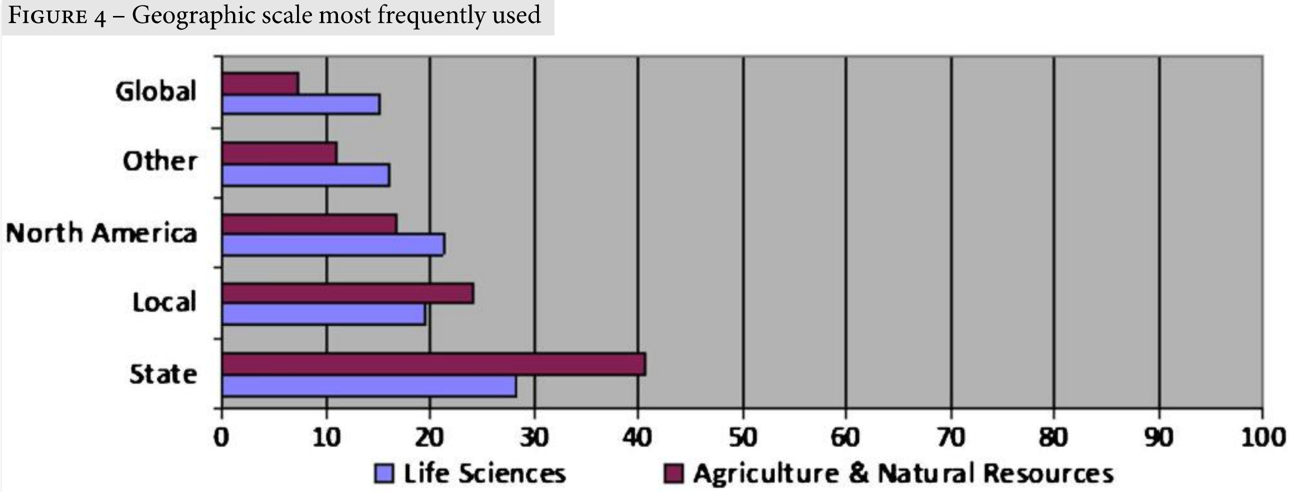
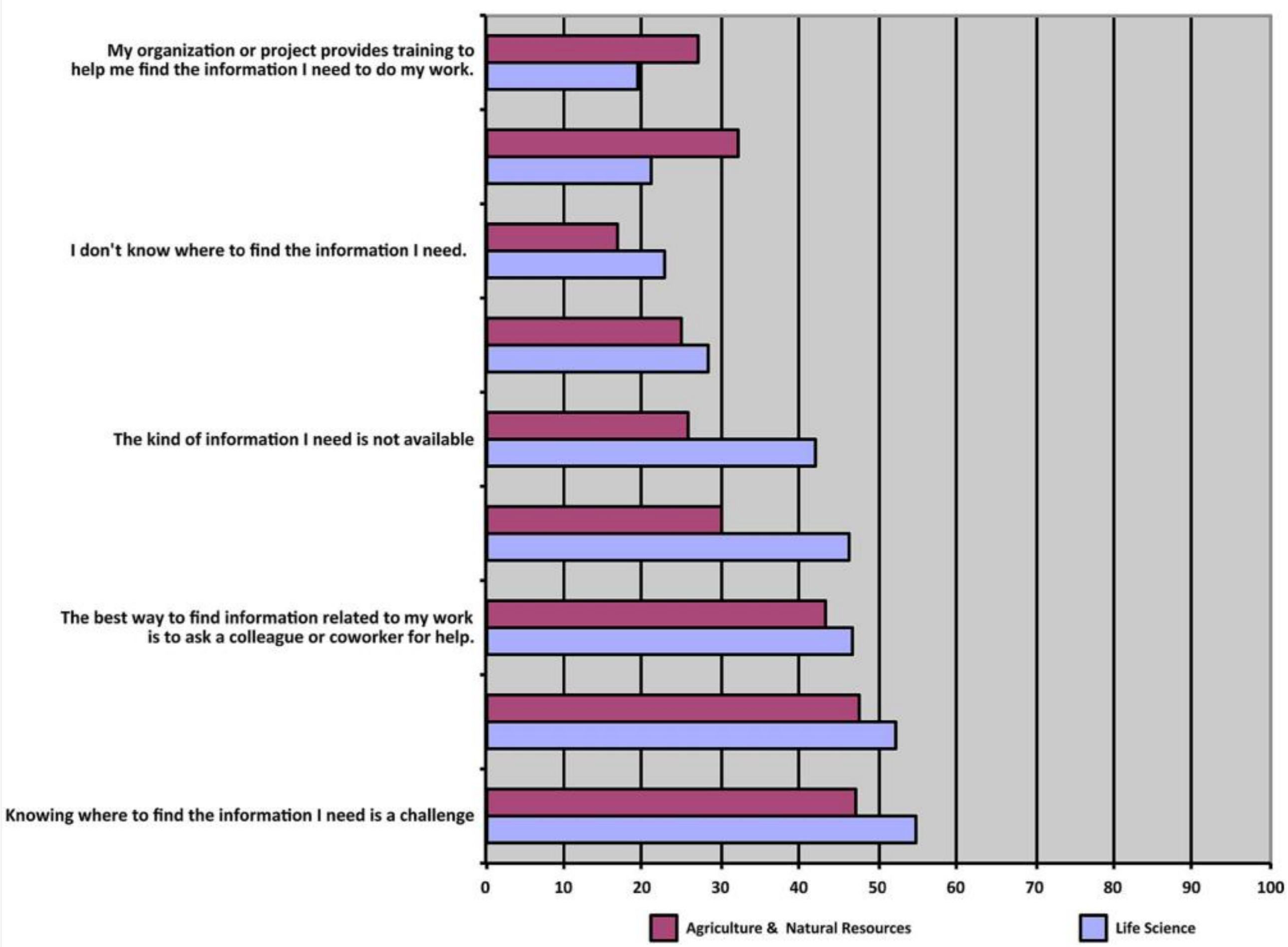


Figure 5 – Percent of agreement with barriers and facilitators for finding biodiversity information



scales more often than life science respondents, while the life science scientists more frequently use information at the global or North American scale.

What are the barriers and facilitators to finding and using biodiversity information? – To understand the barriers and facilitators to finding needed biodiversity information, respondents were asked to rate their experiences finding biodiversity information (Figure 5). Response choices ranged from Strongly Disagree (1) to Strongly Agree (5) with Undecided (3) marking the midpoint. On average, respondents are undecided concerning most of these experiences (means = 2.99–3.2). They more clearly tend to disagree that they already have the information they need to do their work (mean = 2.63) or don't know where to find the information they need (mean = 2.59). They also disagree that their organization or project provides training to help them find the information they need (mean = 2.38). No significant mean differences were found between science disciplines.

Despite these neutral to slightly disagreeing mean responses, more than two thirds of all respondents (67.7%) agree that finding the information they need is difficult. For more than half, knowing "where" to find the information they need is a challenge (52.4%). Perhaps for these reasons, and the fact that only 21.8% agree their organizations provide the training they need to find information, nearly half (45.8%) feel asking a colleague or coworker for help in finding information is the best way to go. Another 40% are disappointed with the amount of time it takes to find what they need and nearly that many (36.6%) feel what they need simply is not available.

Life science researchers are more convinced than agricultural and natural resource researchers that the information they need is not available (Figure 5). They are also more likely to agree they spend too long finding the information they need. These differences are substantial, but not quite statistically significant ($p = .047$ and $.048$ respectively). Agricultural information scientists can also feel good that agricultural researchers are more likely than life scientists to agree their organization provides information search training, and that their agriculture and natural resource colleagues are more likely to feel they already have the information they need to do their work.

When asked to identify what limited them most when looking for the biodiversity information they need to do their work, over one third of respondents, the most for any choice, chose "time" (32.3%) (Table 3). Agriculture and natural resource respondents are less likely to be most limited by a lack of available information and not knowing how to find what they need than life science respondents.

Table 3 – Most limited by . . . (when looking for needed biodiversity information)

	Agriculture & Natural Resources (n = 54)	Life Science (n = 113)	Total (n = 167)
Time	35.2%	31.0%	32.3%
Lack of available information	13.0%	24.8%	21.0%
Lack of appropriate information	17.7%	13.0%	16.2%
Not knowing where to look	15.0%	9.3%	13.2%
*Not being able to access the information that is available	5.3%	16.7%	9.0%
Not knowing how to find what I need	6.2%	13.0%	8.4%

*($p < .05$)

They are significantly less likely than life science respondents to be most limited by not being able to access the information that is available. In other words, agriculture respondents may have better access, or ability to access, the information they need, but they are less likely than life science respondents to know where to find it.

"Time" is also the leading "other" limiting factor in finding needed biodiversity information. Respondents also face limitations from: lack of appropriate information (34.9%), lack of available information (31.4%), not knowing where to look for needed information (31.4%), not being able to access information (27.2%), and not knowing how to find needed information (23.1%). The same patterns between the disciplines noted above are seen among these additional limitations. However, significantly more agriculture and natural resource scientists (45.5%) than life scientists (29.8%) report a lack of appropriate information as an other limiting factor in finding the biodiversity information they need to do their work.

Where do respondents get their biodiversity information? – Respondents consult a wide variety of information sources and systems (Table 4). Most respondents (overall, and in both disciplines assessed) regularly consult 2–5 information sources (58.6%, n = 99), while almost one quarter (23.1%, n = 39) regularly consult six or more. Only 15% are regularly able to consult only one information source. Disciplinary results are similar. In addition, despite being provided with seventeen vetted information

Table 4 – Information sources regularly consulted)

Information Source	Life Science	Agriculture & Natural Resources	Total (n = 169)
	(%)		
*U.S.DA (U.S. Department of Agriculture)	47.4	70.9	55.0
State Environmental or Wildlife Resources Agencies	54.4	49.1	52.7
*NatureServe	42.1	25.5	36.7
*NRCS (Natural Resources Conservation Services)	24.6	49.1	32.5
*NOAA Climate Services	24.6	40.0	29.6
*Other	35.1	18.2	29.6
NCDC (National Climactic Data Center)	15.8	25.5	18.9
LTER (Long-Term Ecological Research Network)	18.4	10.9	16.0
U.S.GS Office of Global Change	14.0	20.0	16.0
Cornell Lab of Ornithology	17.5	9.1	14.8
IPCC (Intergovernmental Panel on Climate Change)	12.3	12.7	12.4
NASA (National Aeronautics and Space Administration, e.g. MODIS or LANDSAT Programs)	11.4	12.7	11.8
U.S. Army Corps of Engineers	8.8	9.1	8.9
NSIP (U.S.GS National Streamflow Information Program)	9.6	7.3	8.9
U.S.A NPN (U.S.A National Phenology Network)	8.8	3.6	7.1
U.S. GCRP (U.S. Global Change Research Program)	4.4	5.5	4.7
NESDIS (National Environmental Satellite, Data and Information Service)	2.6	5.5	3.6
FEMA (Federal Emergency Management Agency)	1.8	5.5	3.0

*($p < .05$)

sources to choose from, one third of respondents regularly consult an "other" information source.

The top five information sources consulted present a mix of federal and state agencies as well as one not-for-profit organization. Not surprisingly, the United States Agriculture Department is the top information source for agriculture and natural resource respondents. However, it is the second most regularly consulted for life science respondents as well. The only information source they are more likely to consult is state agencies. Overall, agriculture and natural resource respondents rely more heavily on the U.S. federal agencies than do the life science respondents. Life science respondents are more likely to consult state, not-for-profit and a variety of other sources. A number of the disciplinary differences seen are large enough to be statistically valid (Table 4).

As any given source of information can also provide more than one information system, respondents were also asked which information systems they regularly consult. Results follow the same general trends as seen with information sources. The full list of information systems polled and their usage rates are summarized in Table 5 to provide a fuller picture of the diversity of respondents' information searching.

What characteristics of biodiversity information sources are most valued? – Southeastern U.S. agriculture and life scientists who responded to this survey have uniformly high standards for the biodiversity information sources they regularly use. Respondents were asked to rate the importance of seven information source attributes on a scale from "not at all important" (1) to "essential" (5): 1) Currency – the information is up to date, 2)

Table 5 –Information systems regularly consulted

Information Source	Life Science	Agriculture & Natural Resources	Total (n = 169)
	(%)		
U.S.DA PLANTS Database	41.2	54.5	45.6
*NatureServe Explorer	31.6	16.4	26.6
Other	25.4	14.5	21.9
National Soil Access System	17.5	29.1	21.3
Birds of North America	23.7	12.7	20.1
Breeding Bird Survey	21.1	16.4	19.5
NOAA's Southern Regional Climate Center	13.2	23.6	16.6
Christmas Bird Count	14.9	9.1	13.0
NBII Portal	13.2	5.5	10.7
AU.S.GS GAP Analysis Portal	8.8	14.5	10.7
*National Weather Service Climate Prediction Center	5.3	20.0	10.1
LTER Data Portal	9.6	7.3	8.9
U.S.FS Climate Change Tree Atlas	7.9	10.9	8.9
Southeast Regional Climate Center's Climate Data	6.1	12.7	8.3
NBII Metadata Clearinghouse	8.8	3.6	7.1
U.S.GS Climate Change Bird Atlas	7.0	5.5	6.5
NAWQA (National Water Quality Assessment) Program	4.4	7.3	5.3
NSIP	6.1	3.6	5.3
U.S.GS Science in Your Backyard	6.1	1.8	4.7
Eastern Brook Trout Survey	3.5	3.6	3.6
U.S. DOE Carbon Dioxide Information Analysis Center	2.6	5.5	3.6
EcoTrends	3.5	1.8	3.0
FEMA Map Service	0.9	5.5	2.4
U.S.FS/LTER CLIMDB/HYDRODB	0.9	5.5	2.4
NOMADS	3.5	0	2.4
Agroclimate	0	5.5	1.8
AcoE Environmental Residue Effects Database	1.8	0	1.2

*(p < .05)

Completeness – the information is comprehensive, 3) Scale – the information is provided at the geographic or temporal scale needed, 4) Usability – the information is easy to use, 5) Trusted source – the information is authoritative, 6) Provenance – the information is well documented, 7) Navigation – the information is easy to find. Mean importance levels range from 4.5 (Trusted Source) to 3.98 (Navigation). No significant differences in mean importance between the disciplines were found. Proportionately, all the attributes measured are important or essential to more than 75% of all respondents. Few disciplinary differences in the proportion of respondents rating these attributes important or essential are seen except in Completeness. 96.2% of agriculture and natural resource respondents rate completeness as important or essential, while only 81.8% of life science respondents do ($p < .05$). Life science respondents rate provenance, trusted source, and scale as more important than completeness. For agriculture respondents, completeness is second only to trusted source.

Discussion

In many ways, this study confirms previous findings on scientists' biodiversity information needs. The scientists in our sample require large amounts of high quality, appropriately scaled and mappable biodiversity information they can access quickly, easily, and preferably online without assistance. And they are having difficulty getting what they need. However, by focusing more on information needs rather than research needs, and by discerning between related life science disciplines, this study also highlights useful findings for information scientists attempting to facilitate biodiversity information access for agriculture and natural resource scientists and other life scientists. These results can also speak directly to scientists, who are often creating the very information their colleagues struggle to find and use, about data curation practices which would increase findability, accessibility and availability.

Past studies have emphasized the importance of biodiversity information integration and identification tools such as data models (Hunt et al. 2007; Vaughan et al. 2007), information finders (Kagan 2006), maps (Laihonen et al. 2003; Theobald et al. 2000) and metadata (Kelling 2008). Here, data models are important or essential to approximately half the respondents. The importance of mapping tools is second only to information search tools, and the mean importance of metadata tools is 3.94 on a scale of Not at all Important (1) to Extremely Important (5). The importance of online information access, noted in the literature (Marcus et al. 2007), and the need for improved information search skills, training and tools (Cullen, Cottingham, and Doolan 2001; Janse 2006) were also found here in open ended responses and in the overwhelming importance attributed to information search tools (> 90% of respondents rate these important or essential). Like the natural resource managers surveyed by NatureServe (Young 2011), respondents to this survey regularly consult a diverse array of information sources including literature, websites, databases, and government agency systems. Lastly, several of the biodiversity information attributes preferred by respondents in previous studies such as currency and usability are also preferred by respondents in this sample.

This study adds to the literature by revealing specific types of biodiversity information and tools needed, information on respondents' experiences meeting these needs, and disciplinary differences. Overall the mean amount of information needed by life scientists that is specifically biodiversity related is greater than it is for agriculture and natural resource scientists ($p < .05$). However, 72% of agriculture and natural resource scientists still say half or more than half of the information they need to do their work relates specifically to biodiversity. One-third of these, as opposed to just over one-fifth of life scientists, have difficulty finding it. Why agriculture and natural resource respondents should have more difficulty than life science respondents remains unclear. These findings are all the more puzzling when one considers the fact that, at least according to these results, agricultural scientists are slightly more likely to agree that their organizations provide the training in finding the information they need.

In terms of biodiversity information types, raw data is needed more than summarized data overall and significantly more so by life scientists than agricultural scientists. However, it is again the agriculture and natural resource scientists who have a significantly harder time finding the raw data than the life scientists. One possible reason is that since agricultural scientists tend to need slightly more summarized biodiversity information than life scientists, they are somewhat less practiced at looking for raw data than life scientists.

In addition, according to these results, life scientists may be somewhat more data savvy than agriculture and natural resource scientists overall. Life scientist respondents are significantly more likely to include data management in their positions than are agricultural respondents. Metadata tools are also significantly more important to life science respondents than to agriculture respondents, perhaps because they are more familiar with them.

As only 22% of respondents say their organization provides training for finding the biodiversity information they need, these results suggest a need for increased information skills training. And because life science and agriculture and natural resource science are highly related, training possibilities such as joint life and agriculture science trainings, peer to peer training, and embedded information scientists should be considered. Agricultural science can be viewed as one application of life science, and researchers in both areas frequently collaborate and/or conduct interdisciplinary research. While disciplinary differences in biodiversity information needs and skills reported here are present, they are not stark. Lastly, nearly half of all respondents state that asking a colleague is the best way to find the information they need.

By embedding themselves with scientists, both agricultural and natural resource scientists and other life scientists, information professionals can achieve a deeper level of knowledge concerning biodiversity information needs. This knowledge can then be used proactively and combined with push technologies such as tweeting, listservs, and blogs to provide needed information directly to scientist colleagues. This decreases the burden on scientists to seek out information professionals, their services and/or their trainings. Whether embedded or not, information professionals might also consider coordinating collegial interactions among scientists to capitalize on both the collaborative nature of agriculture and natural resource and life science work as well as the extant processes of relying on colleagues for finding information.

Time was the primary barrier for all respondents, regardless of discipline. While nothing can increase the amount of time scientists have to find the biodiversity information they need, training, usability analysis of information resources and embedded collaborative relationships may improve efficiency. In addition, having further evidence of the barriers to finding biodiversity information, including time, biodiversity information providers may be able to use these results to streamline and enhance usability and accessibility. Those who wish to target agriculture and natural resource scientists should also note that for agricultural respondents in particular, the importance of completeness as a biodiversity information attribute is second only to trusted source. Life science respondents were significantly less concerned with completeness.

Lastly, life and agriculture and natural resource scientists themselves have much to learn from these findings. It is clear that finding and accessing trusted, appropriate, mappable and available biodiversity information that is complete, usable, well described, well documented, and current takes time, skill, and knowledge as well as familiarity with a number of information sources and systems. However, if all those who generate biodiversity information were to invest time up front in documentation, description, deposition, and management, biodiversity information would be easier to find for all who need it. Agriculture and life science information science professionals are one group that can carry these messages.

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